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EXTENDED ARRAY EVALUATION PROGRAM

Terence W. Harley

Texas Instruments, Incorporated

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EXTENDED ARRAY EVALUATION PROGRAM

Quarterly Report No. 2

1 July 1972 to 30 September 1972

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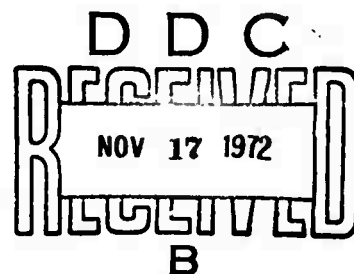
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13. ABSTRACT

This second quarterly report summarizes progress under the Extended Evaluation of ALPA, NORSAR, and VLPE program, Contract number F33657-72-C-0725. Work to date in the following areas is summarized:

- ALPA evaluation
- NORSAR long period evaluation
- NORSAR short period evaluation
- VLPE evaluation
- Network evaluation

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SECTION I

INTRODUCTION AND SUMMARY

This second quarterly report summarizes progress made during the last quarter, 1 July 1972 to 30 September 1972, on the Extended Evaluation of ALPA, NORSAR and VLPE Data Program being conducted by Texas Instruments Incorporated at the Seismic Array Analysis Center in Alexandria, Virginia. The program consists of the following five tasks:

- Continued evaluation of the Alaskan Long Period Array (ALPA)
- Continued evaluation of the long period Norwegian Seismic Array (NORSAR)
- Continued evaluation of the short period Norwegian Seismic Array
- Continued evaluation of the stations of the Very Long Period Experiment (VLPE) network
- Investigation of network processing and analysis techniques.

The software required to perform the evaluation was developed under a previous contract (Contract F33657-69-C-1063).

ALPA evaluation has included routine noise analysis and the processing and analysis of about 150 events from the January-March period. Processing of a suite of summer events from the June-August period is now in progress. A special report entitled "Indirect Estimates of Surface Wave Detection Probabilities" has been submitted for approval. Collateral activities include current studies of multipath propagation and reference waveform matched filtering.

Similar analyses have been performed with the NORSAR long period data. Analysis of the wintertime event suite was almost completed

during this quarter. About 180 events from the suite were selected for NORSAR long period processing. Noise analysis involved the processing of about 25 new noise samples, most exceeding six hours in length. Multipath studies have been conducted on several additional large events.

Under the NORSAR short period evaluation task about thirty new 1971 events have been edited for analysis. A four month delay in receipt of requested data tapes has prevented work on 1972 data. The tapes have now been received and editing of 1972 events has begun. Several software modifications relating to subarray beamforming are in progress.

About 300 events and 80 noise samples from the January-March period have been analyzed with available VLPE data. Processing of the June-August suite is currently in progress.

Under the network evaluation task analysis of available paper seismograms has resulted in a list of over 300 Eurasian events and VLPE station reports of the signal conditions for each. In addition compilation of VLPE noise analysis results for use in the network study has continued. A study of the utility of the complex cepstrum technique for the separation of mixed signals at the VLPE stations is in progress.

SECTION II

ALPA EVALUATION

1. Current Status

Approximately 150 events have been processed and analyzed. These events occurred during the months of January, February, and March, 1972. In addition, analysis of 125 June events has been initiated; seventy of these events have been successfully processed. Forty events were not useable because of interfering events (22), excessive spiking (7), or inability to access the library tapes (11). Fifteen events remain to be completed. A list of July events is being prepared; this list will be expanded to include the month of August in the near future. We then will have two suites of events, the first covering three winter months and the second covering three summer months. Events from these suites also are being processed with NORSAR and VLPE data, thereby providing common coverage at each of the locations being evaluated.

Routine noise analysis has been performed for the period January-May. In general the average noise levels in the 0.025 Hz to 0.055 Hz band are not significantly different than those observed during the summer of 1971 (6 to 10 m μ RMS). Occasionally, however, levels ranging as high as forty m μ RMS are observed. Vertical and horizontal component levels are comparable. RMS levels in the beam outputs usually range from 1.5 to 3.5 m μ , except on rare occasions when they are higher.

During this quarter a detailed study of reference waveform matched filtering was initiated. Because of its seismicity and proximity to the area of interest, the Sinkiang region was selected for study. About ten reference waveforms have been edited for use in this analysis. The object is

to determine the effect of reference waveform length on matched filter performance, and to determine to what extent a suite of reference waveforms will improve the results previously reported for this area.

Special Report No. 1 entitled "Indirect Estimates of Surface Wave Detection Probabilities" has been submitted for approval. A second special report dealing with analysis of multipath arrivals at ALPA is currently in preparation.

2. Future Plans

Routine processing of ALPA events and noise samples will continue during the next quarter. The reference waveform study will continue, and in the event that positive results are achieved will be expanded to include the Kamchatka-Kuriles area.

SECTION III

NORSAR LONG PERIOD EVALUATION

1. Current Status

During the quarter ending 30 September 1972, significant progress was made on the NORSAR long-period array evaluation task. Routine processing on the January 1 to March 20 event ensemble was almost completed. Remaining work consists of detailed analysis for a few particular events. Additional noise samples have been edited and various noise analyses were started.

The January-March ensemble consists of 308 events. The edit summary of this set is as follows:

Total events	308
No data available	<u>27</u>
Edits attempted	281
Bad library tapes	2
Excessive time gaps	35
Data clipped	2
Event mislocated	6
Interference from other events	<u>53</u>
Total edits suitable for further processing	183

Most of the 183 events were beamed and subjected to detection processing by bandpass and matched filtering. Chirp filters have been routinely applied. Reference waveform filters are being applied to some events when a suitable reference waveform is available; however, that processing is only about half completed. Surface wave magnitudes have been measured for all

events detected after bandpass filtering. Magnitude estimates for events detected with matched filters are being deferred until good matched filter improvements are obtained.

Processing was started before USCGS PDE information was obtained for many events. Several of these events were found to have deep epicenters and were deleted from the ensemble.

Some additional investigation of multipath phenomena was made using a few large events ($m_b \geq 5.0$). This work included estimating the group velocity profiles, intersite signal power variations, and frequency-wavenumber (f-k) spectra.

Noise analysis was continued using 25 new samples covering the period 5 January to 23 April 1972. All but 5 samples were 6 or more hours long, but contain a few unreported events which must be deleted before further processing. Crosspower matrices have been formed for most of the edited samples.

As mentioned in the last monthly report, occasionally we have had problems with data in which various components of a site are switched or inverted. Presumably this occurs after maintenance or testing. This problem is particularly troublesome because the amount of data precludes plotting each component of every site for every event. To control this problem we now are plotting the full data for selected large events occurring about two or three weeks apart; these plots are examined to identify "bad" sites which will be deleted from routine processing. NORSAR personnel will be advised so that they can take corrective action.

2. Future Plans

Processing has just begun on an ensemble of 125 events from June 1972. This will be continued during the next quarter.

Noise analysis will continue through this quarter. MCF's will be designed and applied both to the full array and to various combinations of 5 to 8 sites. Additional noise edits will be obtained past day 114 to observe the change in the noise field to "summertime" status.

Periodic checks of site data for proper orientation will be continued.

SECTION IV

NORSAR SHORT PERIOD EVALUATION

1. Current Status

During the first part of the period July 1 - September 30, 1972 routine NORSAR short period processing continued. Thirty additional signals and one noise sample were processed through plane-wave beamforming. In late July and August attention was given to two critical and closely related problems that had been encountered in previous processing.

The first of these, the strong dissimilarity among subarray beams for "close" ($\Delta < 30^\circ$) events and the consequent inability to determine internally consistent sets of delay anomalies for array beamforming led to an examination of how much signal loss was occurring in beamforming at the subarray level. Examination of single sensor to reference single sensor cross-correlation functions showed an error of 0.1 seconds in the theoretical plane-wave delays for one to three sensors in every subarray. This discrepancy pointed to the necessity of adding to NORSPECT (the program that performs subarray-level beamforming) the capabilities to:

- Use adjusted delays chosen by the analyst (or the program) from examination of cross-correlation functions rather than plane-wave delays;
- Calculate powers, spectra, spectral ratios, etc., for a signal gate arbitrarily selected by the analyst rather than for the entire sample, so that the effectiveness of the use of adjusted delays can be evaluated.

It seems quite possible, at this point, that the use of adjusted delays in NORSPECT may offer the additional benefit of improved detection capability, in view of the importance of the high end of the signal spectrum in the detection of marginal events.

The other problem, that of visually evaluating the effects of beamforming on low-magnitude signals, is being dealt with by adding to NORSPECT the capability to:

- Apply either an ordinary bandpass filter, the standard detection filter used in the final program, or a 32 point filter arbitrarily chosen by the analyst.
- Plot all 132 single sensor traces.

Coding of these additional software capabilities is under way.

2. Future Plans

During the next quarter, the program changes itemized above will be completed and their effectiveness analyzed in reprocessing previous problem events, marginal non-detections and "close" events. These added capabilities will become part of the normal processing sequence for new events. Routine processing of events and noise samples also will continue, with emphasis on 1972 events also processed under the long period NORSAR task.

SECTION V

VLPE EVALUATION

1. Current Status

Processing of about 300 events and 80 noise samples from the January-March period has been completed. This includes preparation of film playbacks for these data. Tapes covering this time interval for the Israel and Thailand stations were received after completion of the processing above. As a result it has been necessary to form a new merge tape for these two stations. Processing of the Israel and Thailand data, and preparation of the corresponding film playbacks is currently in progress.

Processing of the June-August data has also been initiated. Again, however, data tapes from the Thailand and Spain stations have not been received. If these are received at a later date a second merge will again be required.

2. Future Plans

Routine processing and analysis of the winter and summer event suites will continue.

SECTION VI

NETWORK EVALUATION

1. Current Status

Analysis of available VLPE paper seismograms is essentially complete, providing a list of over 300 Eurasian signals and VLPE station reports of the signal conditions for each. Summaries of the VLPE stations as a network for these data are being prepared.

Complex cepstrum analysis of those events catalogued as "mixed" (the expected signal arrival time contained a signal from some other source) has been started for evaluating the usefulness of this procedure in indicating the presence of the wanted signal, in a situation where various sets of the network stations show mixing. A parallel effort to evaluate various filter settings for the complex cepstrum program is being performed on a mixed signal model of chirps. Phasing, relative amplitude, chirp signal lengths, and other factors are being varied in the model to test the resolution of the complex cepstrum technique.

Systematic collection of signal-free one-hour length noise samples at each station has been continued and the resulting power spectra are being converted to RMS ground motion (corrected for the seismograph system response). Over 250 samples have now been collected in 1972 alone (some earlier data are available), but data are essentially lacking at this time from the Charters Towers station (digital recording system difficulties) and Eilat (no digital tapes and unreadable digital tapes).

2. Future Plans

Once the operating characteristics of the complex cepstrum

program have been determined from modeled mixed signals, we plan to systematically investigate most of the signal mixes observed in the paper record analysis. From this investigation we hope to be able to improve the network capability for signal detection by improving the capability at single element stations.